Fatigue Countermeasures Overview

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U.S. Naval Aeromedical Conference
13 Jan 2015

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Fatigue Defined

- ICAO says fatigue is: *A physiological state of reduced mental or physical performance capability resulting from sleep loss or extended wakefulness, circadian phase, or workload (mental and/or physical activity) that can impair a crew member's alertness and ability to safely operate an aircraft or perform safety related duties.*
  - Extended wakefulness or chronic sleep restriction depletes the **sleep reservoir** *(Homeostatic mechanism)*
  - Working non-standard or variable schedules disrupts the **circadian rhythm** *(Circadian mechanism)*
  - And trying to perform too quickly after awakening from sleep or a nap is impaired by **post-sleep grogginess** *(Sleep inertia component)*

Akerstedt J, Folkard S. (1996). Predicting sleep latency from the three-process model of alertness regulation. Psychophysiology, 33:385-389.

What we know about fatigue and mishaps

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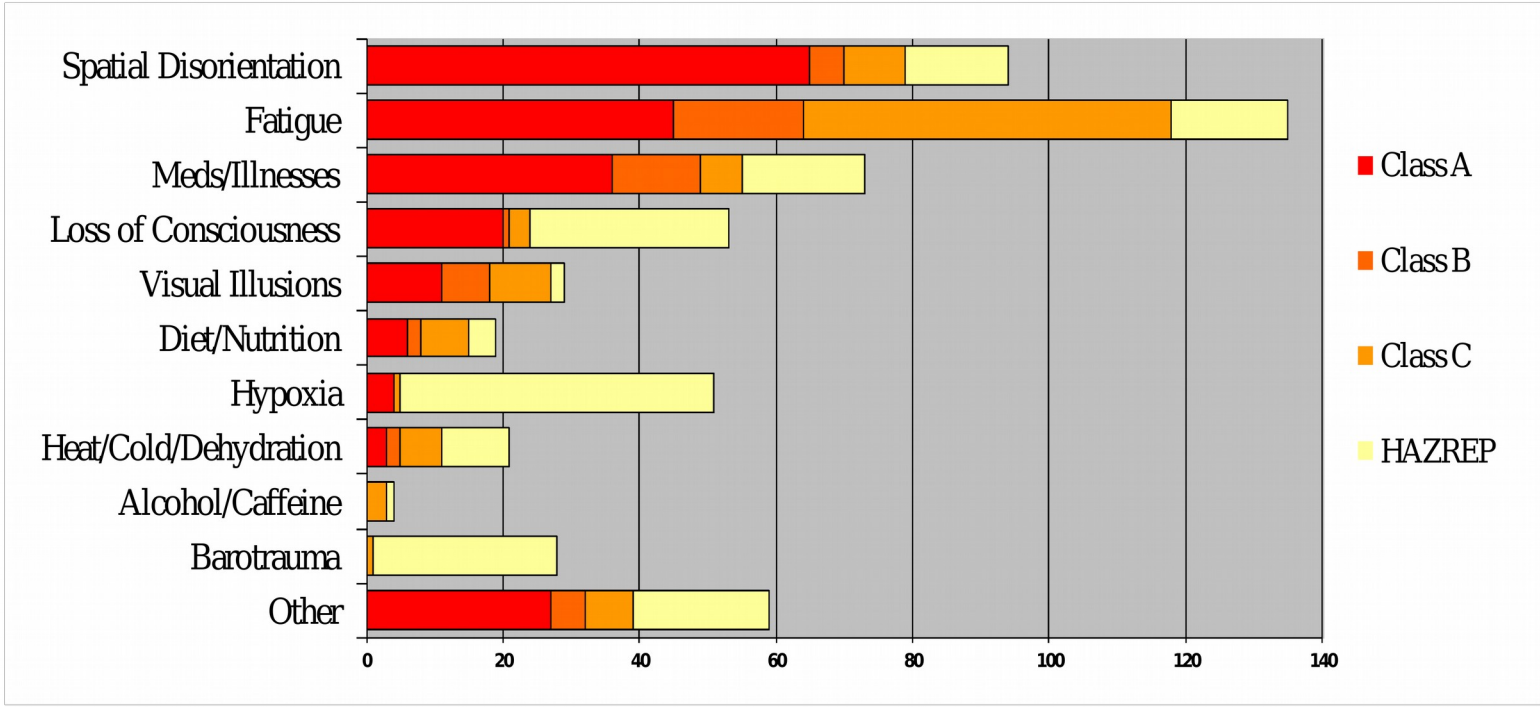
Aeromedical factors cited in recent Naval aviation mishaps and flight hazards



CAPT L. Mandel; NAVSAFECEN data from Mr. John Scott; FY's 1990-2011

The Basic Mechanisms

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Depleted **sleep reservoir** due to acute sleep loss or chronic sleep restriction

Homeostatic component

Low-point in the **circadian rhythm** due to working when mother nature intends sleep

Circadian component

Sleep inertia from trying to perform too quickly after awakening

Inertia component

Folkard, S. and T. Akerstedt, (1991) A three-process model of the regulation of sleepiness and alertness. In Ogilvie, R. and Broughton, R. (eds.) Sleep, arousal and performance: problems and promises, Boston, Birhhauser, 1991:11-26 .

Homeostatic Mechanism

- Time since the last sleep episode is an important part of the fatigue equation.
- Homeostatic sleepiness is low after sleep, but increases as time passes.
- At night, sleepiness is high because homeostatic sleep pressure is high.
- Sleep restriction progressively increases homeostatic pressure.
- You cannot train yourself to get by on less sleep.

Circadian Mechanism

- Time of day (body-clock time) is another part of the fatigue equation.
- Exposure to sunlight is a major determinant of the body clock.
- Maximum sleepiness usually is predawn and right after sunrise (0200-0800).
- After changing to a new schedule, the sleepy time may occur at work.
- Constant schedule changes will disturb internal rhythms and may impair sleep and subsequent performance.

Mechanisms Combined

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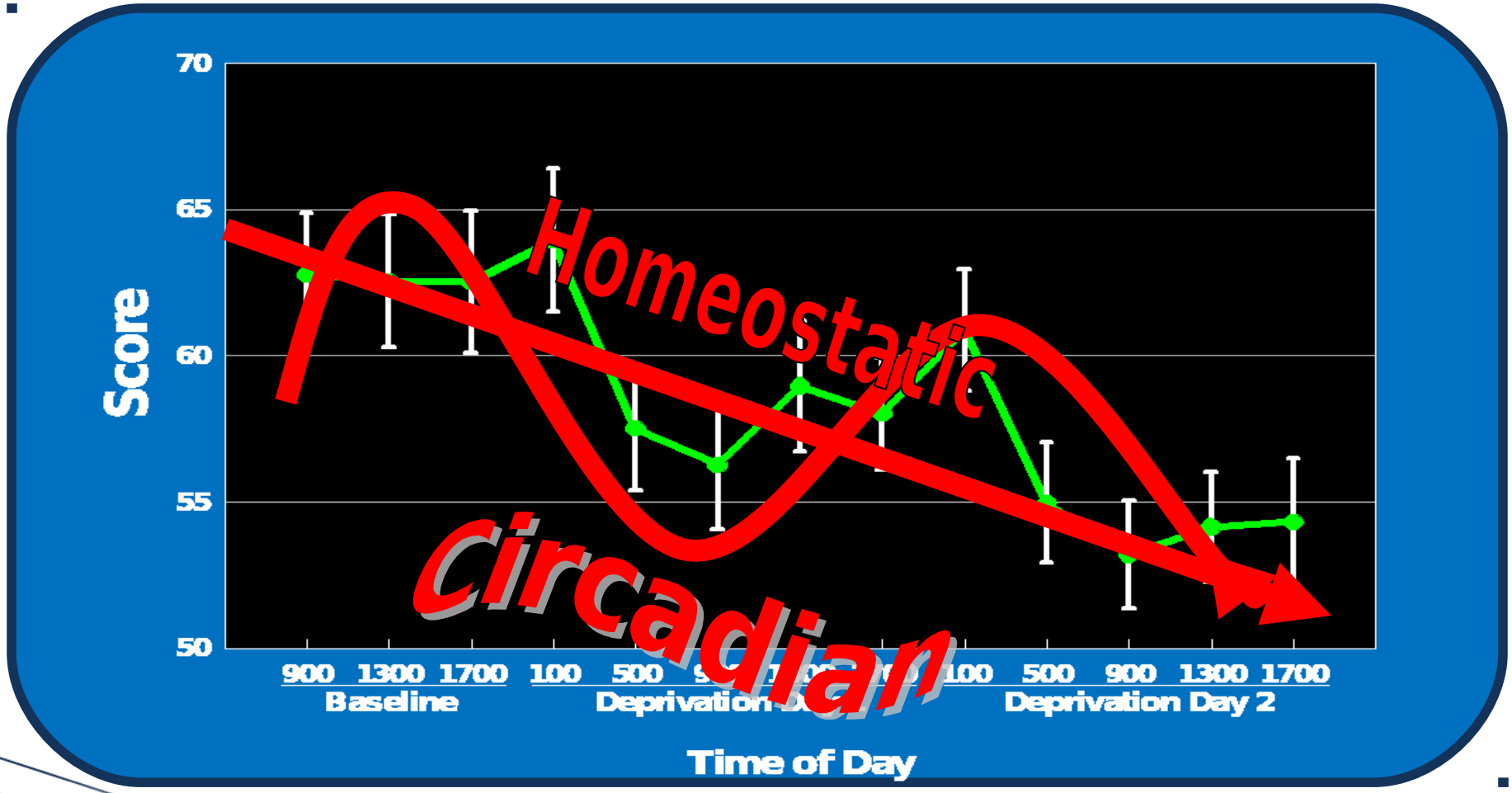

Sleep Inertia

- Sleep inertia is the brief period of grogginess that occurs upon awakening
- In most contexts, sleep inertia is not a concern since it dissipates in about 20-30 minutes
- However, when napping is used as a fatigue countermeasure, sleep inertia can cause problems
- Safety may be compromised if performance is required too quickly after awakening

How Much Sleep?

- A “catch all” answer would be “whatever allows you to function well throughout the day”
- There are individual differences in sleep needs
- The average adult needs 7 to 8 hours per night

Age and condition	Average amount of sleep per day
Newborn	up to 18 hours
1–12 months	14–18 hours
1–3 years	12–15 hours
3–5 years	11–13 hours
5–12 years	9–11 hours
Adolescents	9–10 hours
Adults, including elderly	7–8 (+) hours
Pregnant women	8 (+) hours

Factors that Affect Sleep

Age	Sleep continuity / amount of SWS decrease with age
Sleep History	SWS increases after sleep deprivation REM sleep increases on 2nd night after deprivation REM sleep increases after withdrawing REM-suppressing med's
Circadian Effects	Onset is faster when body temperature is low Time zone crossings can be similar to day sleep of night workers Normal SWS/REM pattern may reverse when sleep is delayed
Environmental Temperature	Temperature extremes can cause frequent awakenings *18-21 degrees C seems to be the best room temp for sleep*
Medication, Alcohol, etc.	Chemical interventions produce several effects
Sleep Disorders	Medically-recognized disorders affect sleep

The *current* best practices for managing fatigue

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1) Avoid Sleep Restriction

- Insufficient sleep leads to drowsiness while: watching TV, in meetings, working, driving, or in sedentary tasks
- If present, evaluate the amount of time spent asleep each night and adjust accordingly.
- To determine your physiological sleep need:
  - Gradually lengthen the sleep period until daytime sleepiness subsides.
  - Track natural sleep / wake rhythms during vacation
- Ignore what people say about their own sleep; individual sleep needs differ quite a bit

Small Amounts Matter!

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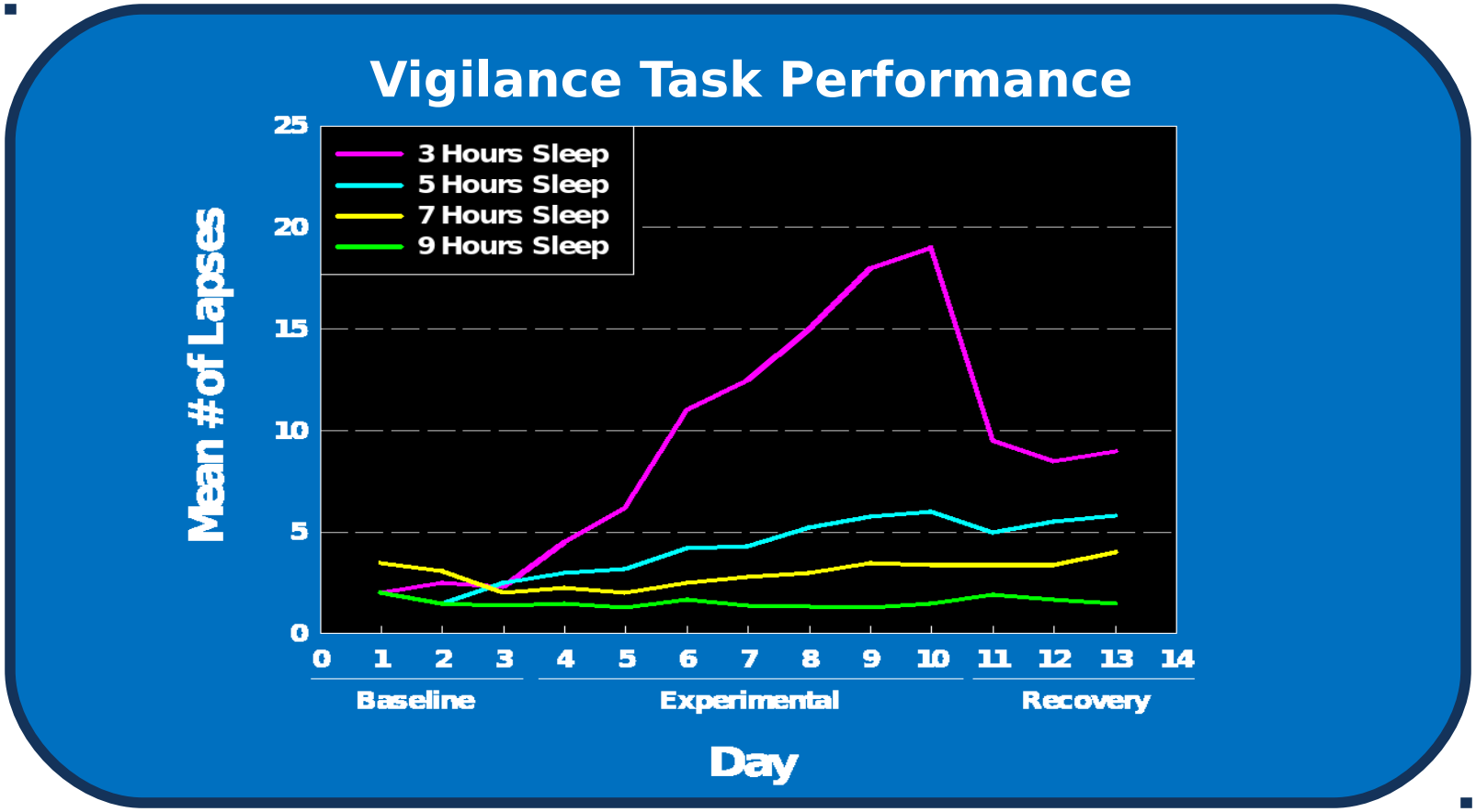

Johnson ML et al. (2004). Modulating the homeostatic process to predict performance during chronic sleep restriction. Aviat Space Environ Med, 75(3 Suppl):A141-6.

Recovery is Slow

- Most research indicates that recovery from chronic sleep restriction occurs slowly
  - After 7 days of sleep restricted to 7 or fewer hours, 3 nights of 8 hours sleep was not sufficient to recovery cognitive functions
- People who are pre-loaded with sleep prior to sleep restriction recover more quickly than those who are not (Rupp et al., 2009)

Rupp TL et al. (2009). Banking sleep: realization of benefits during subsequent sleep restriction and recovery. Sleep, 32(3):311-321.

Fatigue Tolerances Differ

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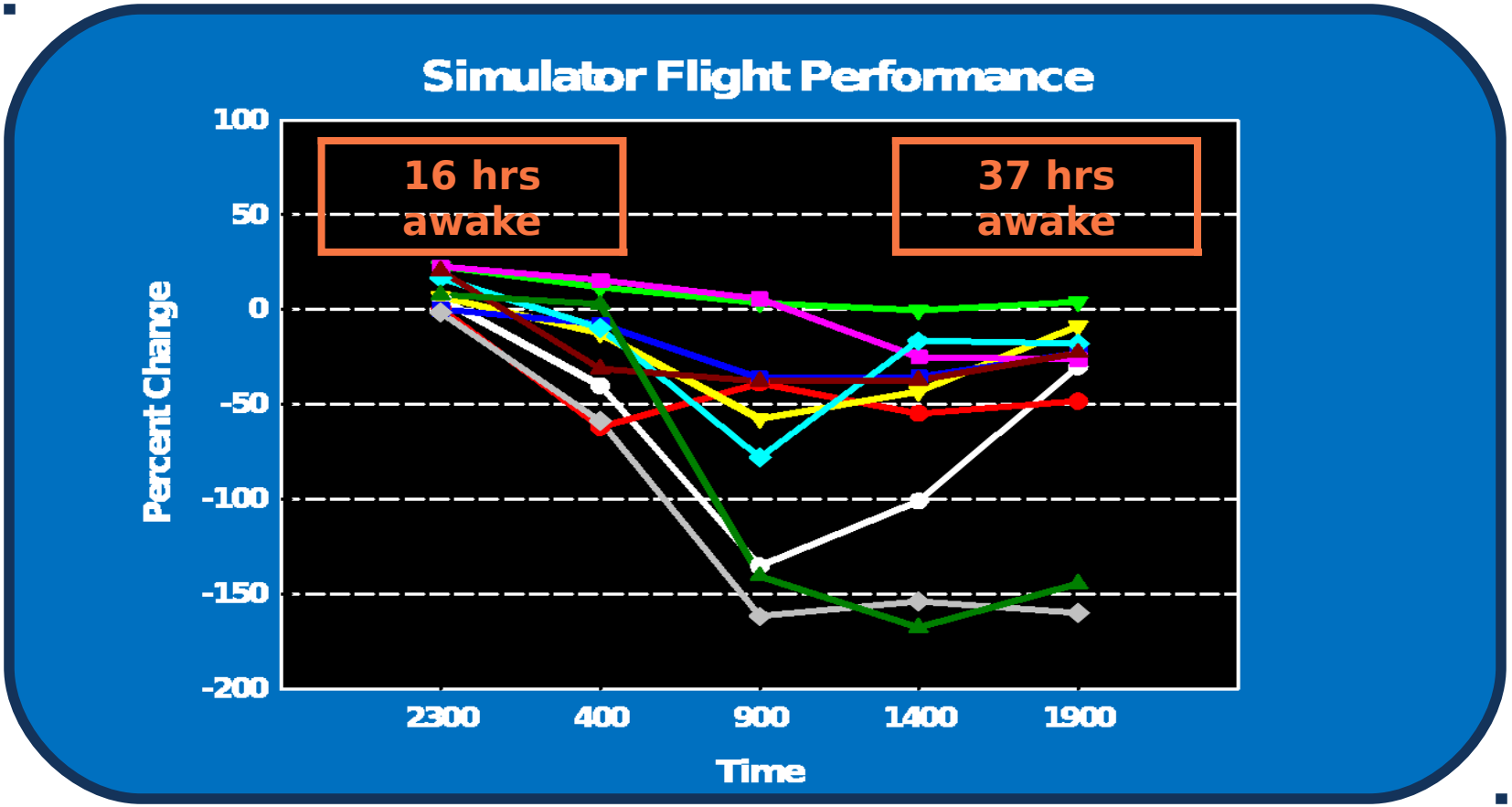

Caldwell JA et al. (2005). Are individual differences in fatigue vulnerability related to baseline differences in cortical activation? Behavioral Neuroscience, 119:694-707.

2) Use Good Sleep Habits

- Stick to a consistent wake & bedtime every day
- Use the bedroom only for sleep and sex
- Resolve daily dilemmas outside of the sleep area
- Engage in a consistent “getting ready for bed” routine as often as possible
- Establish an exercise routine and stick to it
- Create a quiet and comfortable sleep environment
- Consume your last caffeine at least 4 hrs prior to bed
- Avoid alcohol as a sleep aid
- Avoid taking naps during the day
- Place the alarm clock where it can’t be seen during nighttime wakeups

The caffeine–insomnia cycle

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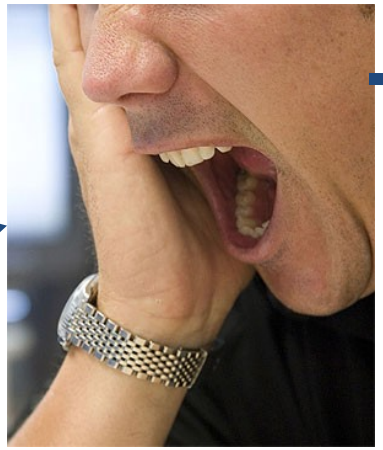

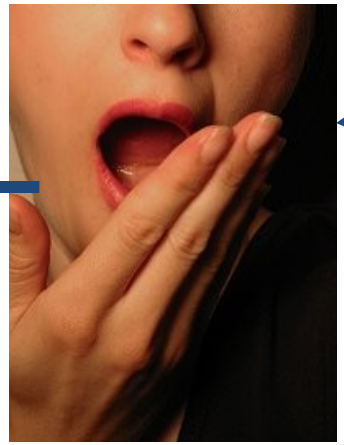

3) Carefully Plan Rosters

- Schedule design is not easy or straightforward
- No scheduling approach eliminates all problems in working non-standard hours
- Consideration must be given to:
  - Work setting and nature, types of employees
  - Fatigue and circadian impact of desired schedule
  - Effect of schedules on employee morale
- Consider as many of the follow scheduling recommendations as possible!

Scheduling Considerations (1)

- Provide at least 2 full days off after each night rotation ends.
- Create higher acceptance of the schedule system by allowing employee input.
- Provide education about needs of people working non-standard hours for the family.
- Pay special attention to workload distribution and staffing levels, especially for night crews.
- Rotate duties if possible to help with monotony.
- Avoid long night duty periods.
- Increase light levels at night as much as possible.

Scheduling Considerations (2)

- Emphasize the importance of double-checking work performed at night.
- Ensure that managers and schedulers have experience with working non-standard schedules.
- Provide education on sleep/body-clock to new managers and schedulers.
- Make sure those working at night have full access to resources available to day workers.
- Educate the personnel about circadian rhythms, sleep and night work and appropriate fatigue countermeasures.

Other General Considerations

- Type of worker:
  - Older workers less tolerant due to flatter rhythm and lower sleep efficiency
  - Younger workers less tolerant due to disrupted social activities
  - Morning people less tolerant to night work than Evening people and Night people less tolerant to morning schedules than Morning people
- Speed of rotation:
  - Acute fatigue higher with 2 day rotations, but cumulative fatigue is lower
  - Adjustment greater with >7 days/shift, but fatigue adds up for night crews
- Recovery time:
  - The goal is 8 h of sleep--*11 hours off between duty periods is the minimum!*
- Length of duty period:
  - Risk increases as a function of time on duty--*do not exceed 12 h (but in actuality, a max of 9 hrs is better)*
- Direction of rotation:
  - Clockwise rotations are easier and better than counterclockwise

Scheduling Aids Can Help

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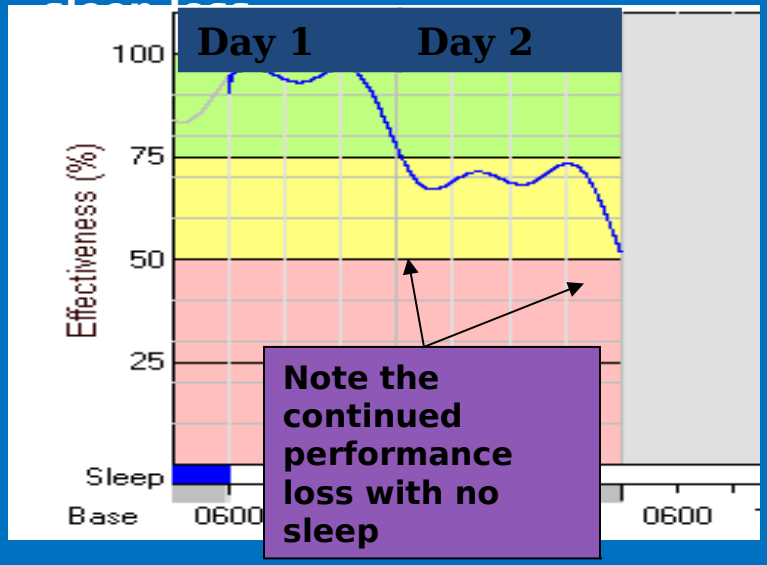
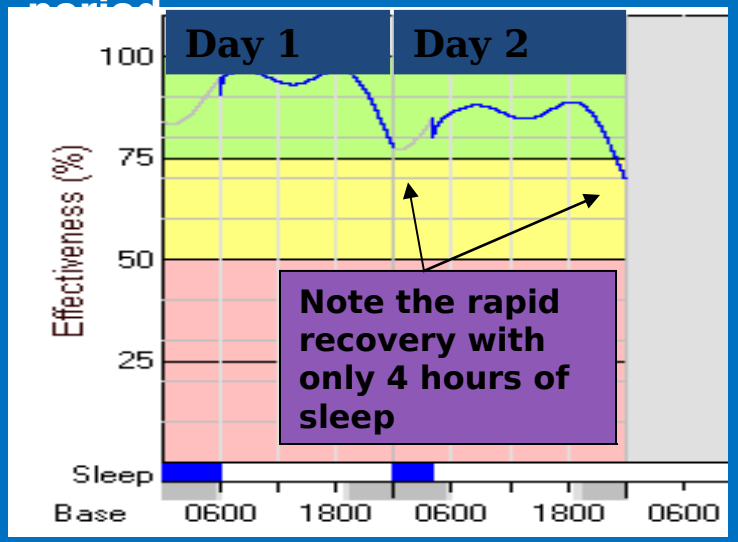
Performance decrement with sleep loss



Improvement with a short sleep period



Fatigue Avoidance Scheduling Tool (FAST)

Hursh SR et al. (2004). Fatigue models for applied research in warfighting. Aviat Space Environ Med, 75(3 Suppl):A44-53.

4) Use Light Exposure

- Light is a powerful modulator of non-visual functions including alertness and performance
  - Bright light is best, but dim light has effects too
  - In some blind people light exposure can induce responses
  - Non-visual responses are maximally sensitive to blue light
- Bright light is known to reset the body clock
  - Light in the morning advances the rhythm
  - Light in the evening delays the rhythm
  - *At best, light can shift the clock 3 hrs/day*
- Light exposure, also has acute effects
  - Typically within 30 minutes
  - Enhances cognitive performance and physiological alertness

Monochromatic Light

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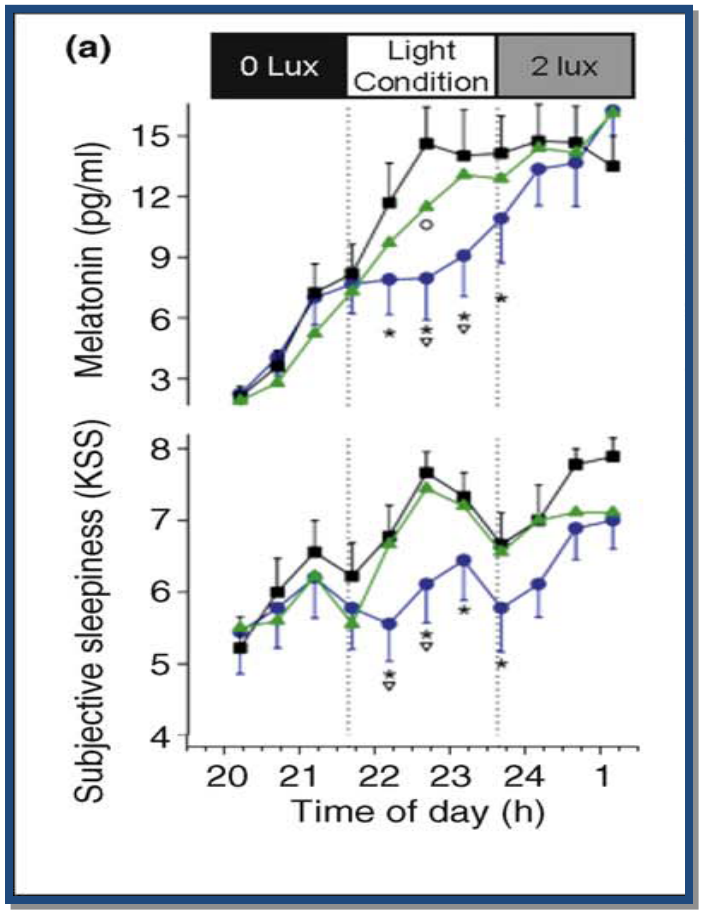

Effects of a:

- ***2-h darkness period***
- ***2-h monochromatic light at 460 nm***
- ***2-h monochromatic light at 550 nm***

Started 11.5 h after habitual wake time

Vandewalle G, Maquet P, Dijk D-J. (2009). Light as a modulator of cognitive brain function. Trends Cogn Sci, 13(10):429-438.

5) Consider Melatonin

- Helps adjust to new shifts
- Doses of 0.5-5 mg can shift circadian rhythms
- Better at advancing than delaying the rhythm
- Time of dose is crucial to its effectiveness
  - Natural melatonin is normally secreted at night with onset beginning before bedtime
- Effectiveness varies greatly by individual
- At best, melatonin can shift the body clock about 1 hour per day
  - Effects on night-time performance are minimal

Shifting The Natural Curve

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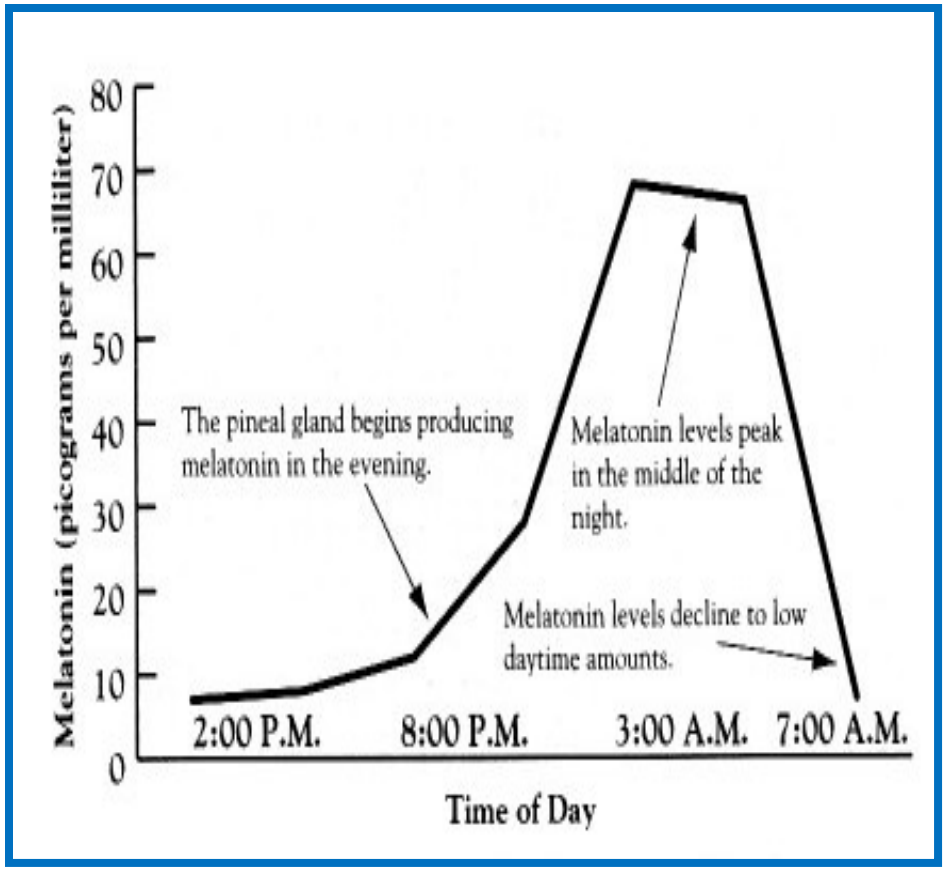
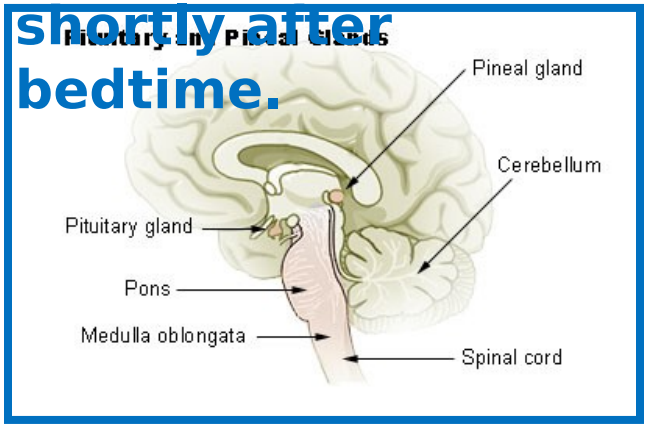


The melatonin produced by the pineal gland normally peaks shortly after bedtime.



6) Consider Hypnotics

- Prescription sleep medications are sometimes viable
- Medications that improve daytime sleep can enhance nighttime performance
- Medications can help with “out of phase” sleep right after a shift rotation or travel
- Restoril®, Lunesta®, Ambien®, or Sonata® are some of the short-term options
- If being used to help with circadian readjustment, limit use to 3-4 days

Zolpidem Improves Nap Quality

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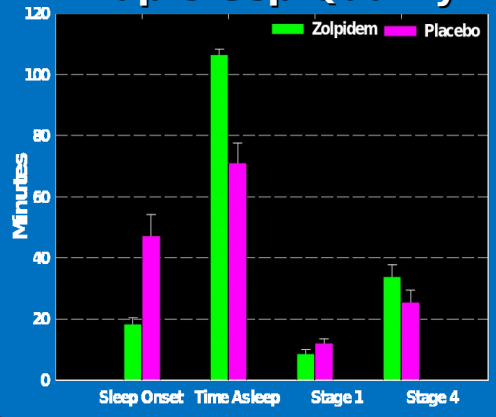
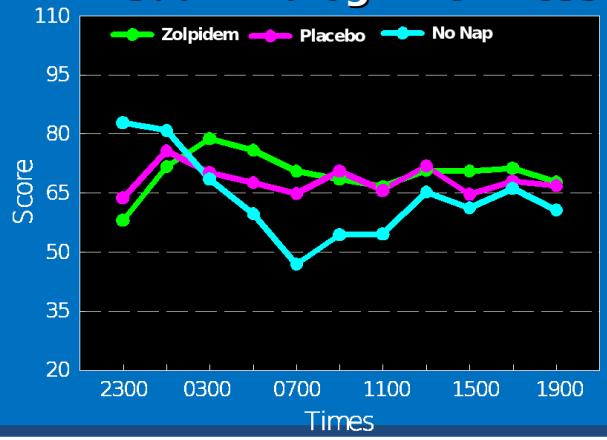
- Three sleep-deprivation periods (rest, zolpidem nap vs placebo nap)
- 10-mg doses/placebo given at 2100 prior to a 2-hr nap or rest period
- Various cognitive and mood testing was conducted at 5-hour intervals

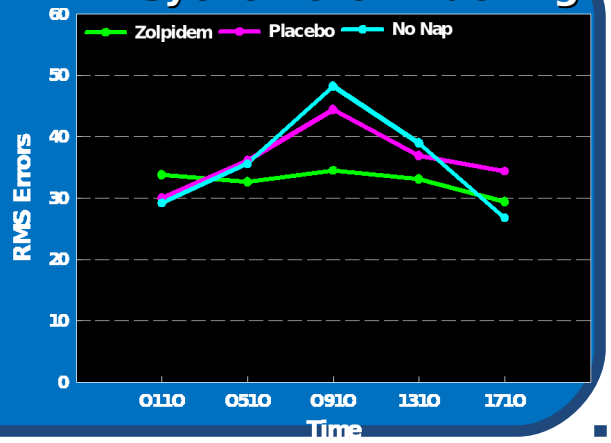
Nap Sleep Quality



Visual Analog- Alertness



Psychomotor Tracking



Caldwell JA, Caldwell JL. (1998). Comparison of the effects of zolpidem-induced prophylactic naps to placebo naps and forced-rest periods in prolonged work schedules. Sleep, 21:79-90.

Temazepam & Night Performance

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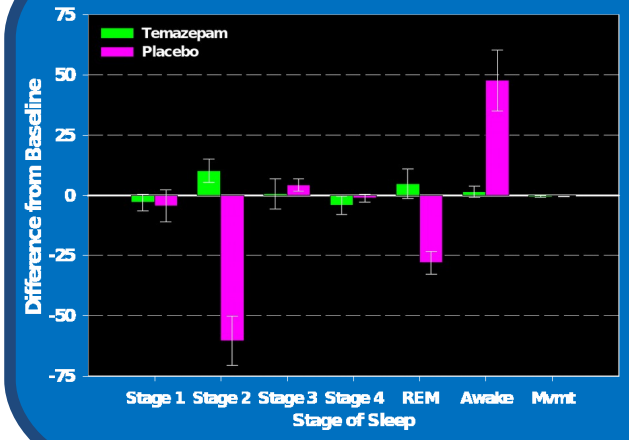
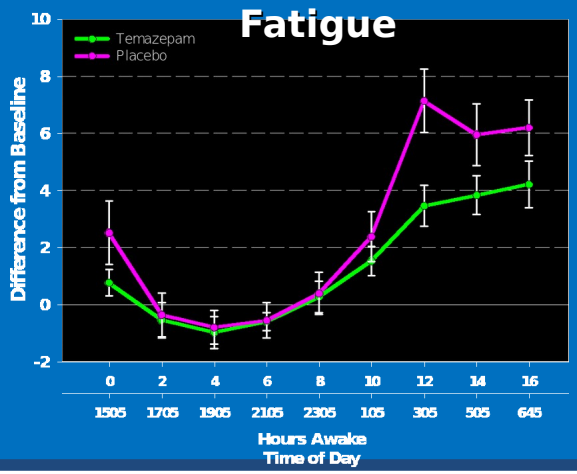
- Three nights of work with daytime sleep (temazepam vs placebo)
- 30-mg dose/placebo given at 0630 prior to an 8-hr sleep period
- Flight simulation and other testing was conducted at 4-hr intervals

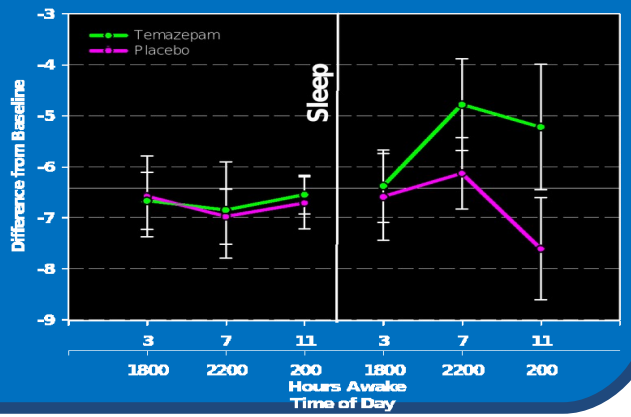
Daytime Sleep Quality



Profile of Mood States-Fatigue



Nighttime Flight Performance



Caldwell JL et al. (2003). Improving daytime sleep with temazepam as a countermeasure for shift lag. Aviat Space Environ Med; 74,153-163.

7) Employ Nap Strategies

- When schedule issues prevent adequate sleep, naps can help maintain performance.
- Naps can be used ***proactively*** to maintain performance during a subsequent period of wakefulness or before the start of duty.
- Naps also can be used ***strategically*** to arrest performance declines that occur from fatigue.
- Short naps of only 30-45 minutes are better than getting no sleep at all.
- Even a 5- to 10-minute nap is better than nothing.

Naps Can Bridge the Gap

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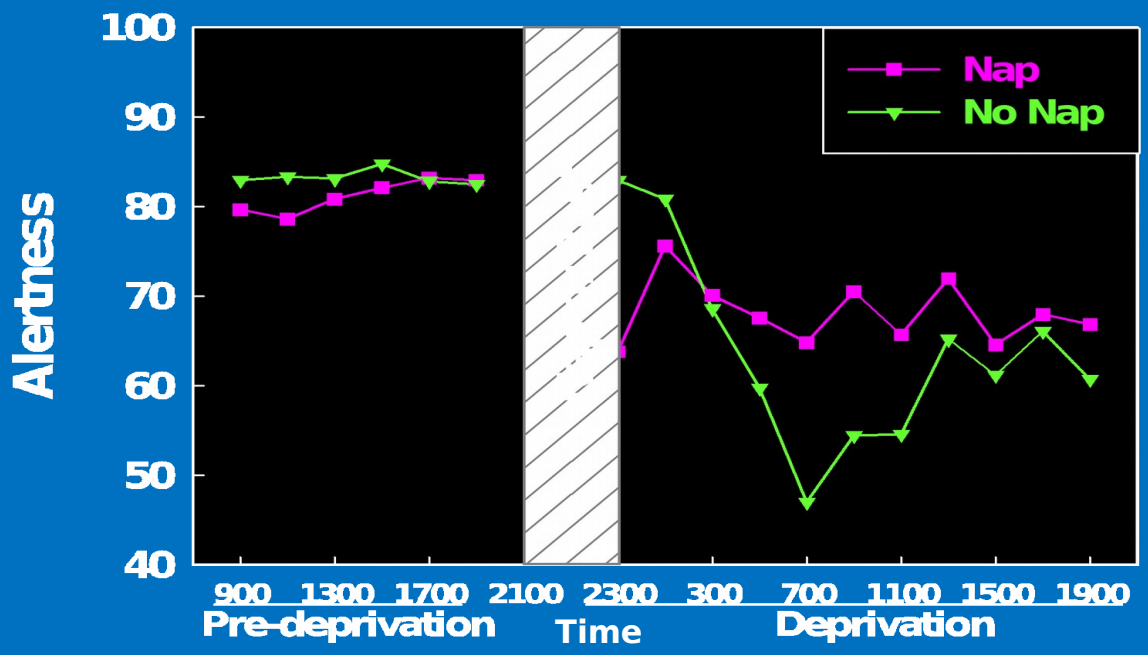

Caldwell JA, Caldwell JL. (1998). Comparison of the effects of zolpidem-induced prophylactic naps to placebo naps and forced-rest periods in prolonged work schedules. Sleep, 21:79-90.

Down-side of naps: Sleep inertia

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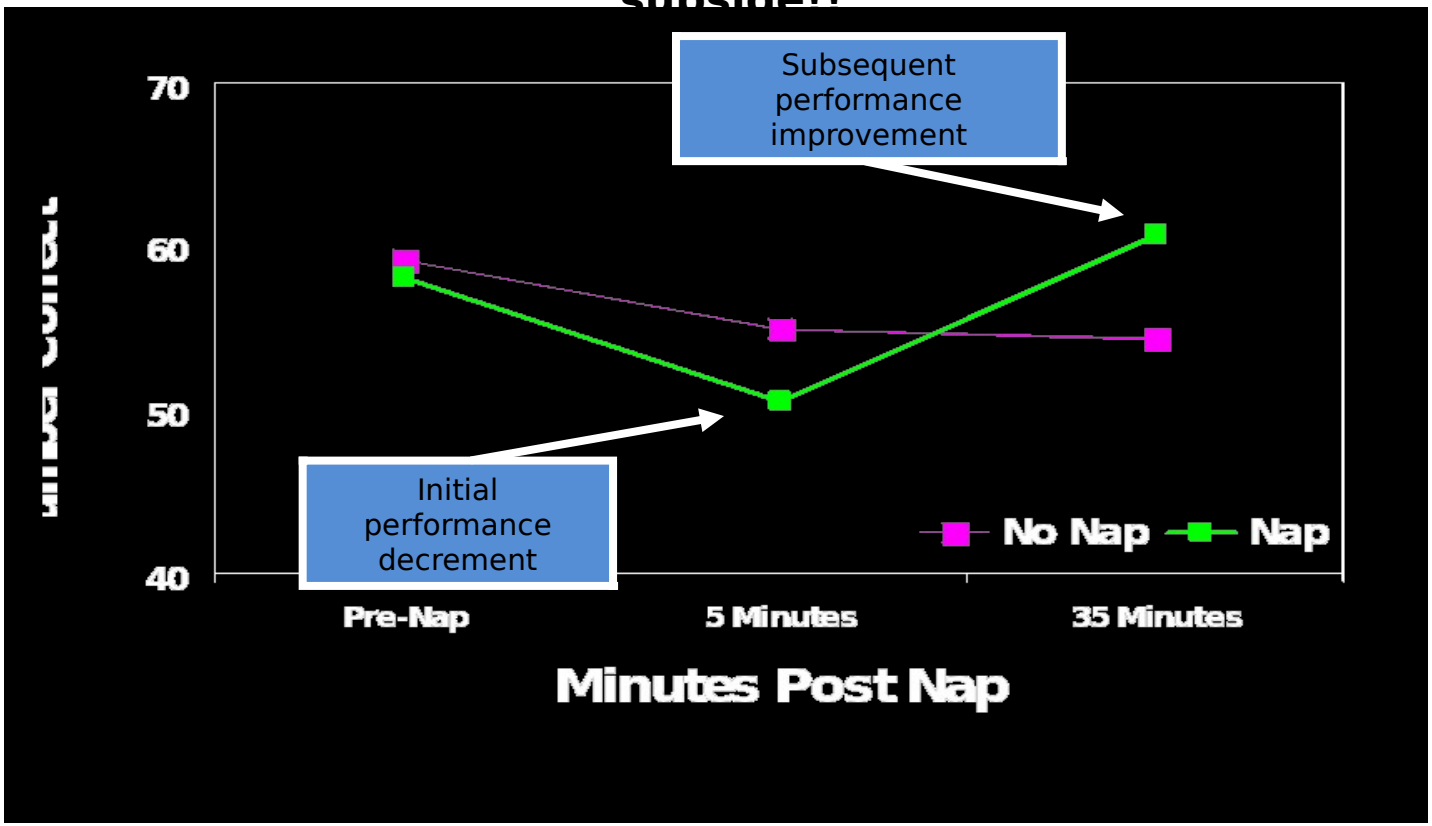
Remember to allow 20-30 minutes post-nap for grogginess to subside!!



Adapted from Tietzel AJ, Lack LC. (2001). The short-term benefits of brief and long naps following nocturnal sleep restriction. Sleep, 24:293-300.

Overcoming Sleep Inertia

- Effects are more severe on executive functions than simple calculations or actions
- Inertia is worse when:
  - Awakening from deep sleep
  - Awakening during the circadian trough
  - Awakening from sleep taken after sleep deprivation
- Effects typically subside in 15-30 minutes naturally
- These strategies may speed up the process:
  - Bright lights
  - Physical activity
  - Upright posture
  - Caffeine
- Crew resource management (CRM) is important!

8) Use Stimulants

- When adequate sleep is impossible, stimulants can help mitigate sleepiness
- Most readily-available options are
  - Caffeine, modafinil (Provigil), amphetamine (Dexedrine)
- Studies report significant improvement in alertness and performance
- Prescription stimulants
  - Often are not permitted in work environments
  - When permitted, precise records must be kept
  - Proper medical oversight is a must !!!

Caffeine

- When adequate sleep is impossible, caffeine can help mitigate sleepiness.
- Effective caffeine doses range from 200-600 mg (limit daily max to 1000 mg).
- Caffeine starts working in about an hour, and the effect lasts about 4 hours.
- Use judiciously--tolerance develops quickly.

Common Sources of Caffeine

1 cup tea=	50 mg	1 Coke=	50 mg
1 Mountain Dew=	55 mg	1 Hot cocoa=	14 mg
2 Excedrin Xtra. Str.=	130 mg	1 cup Maxwell House=	100 mg
1 Max. Str. NoDoze=	200 mg	Chocolate milk (1OZ)=	3-6mg
2 Jolt Caffeine Gum=	100 mg	Snapple Lemon Tea=	31.5mg

Caffeine Can Attenuate Fatigue

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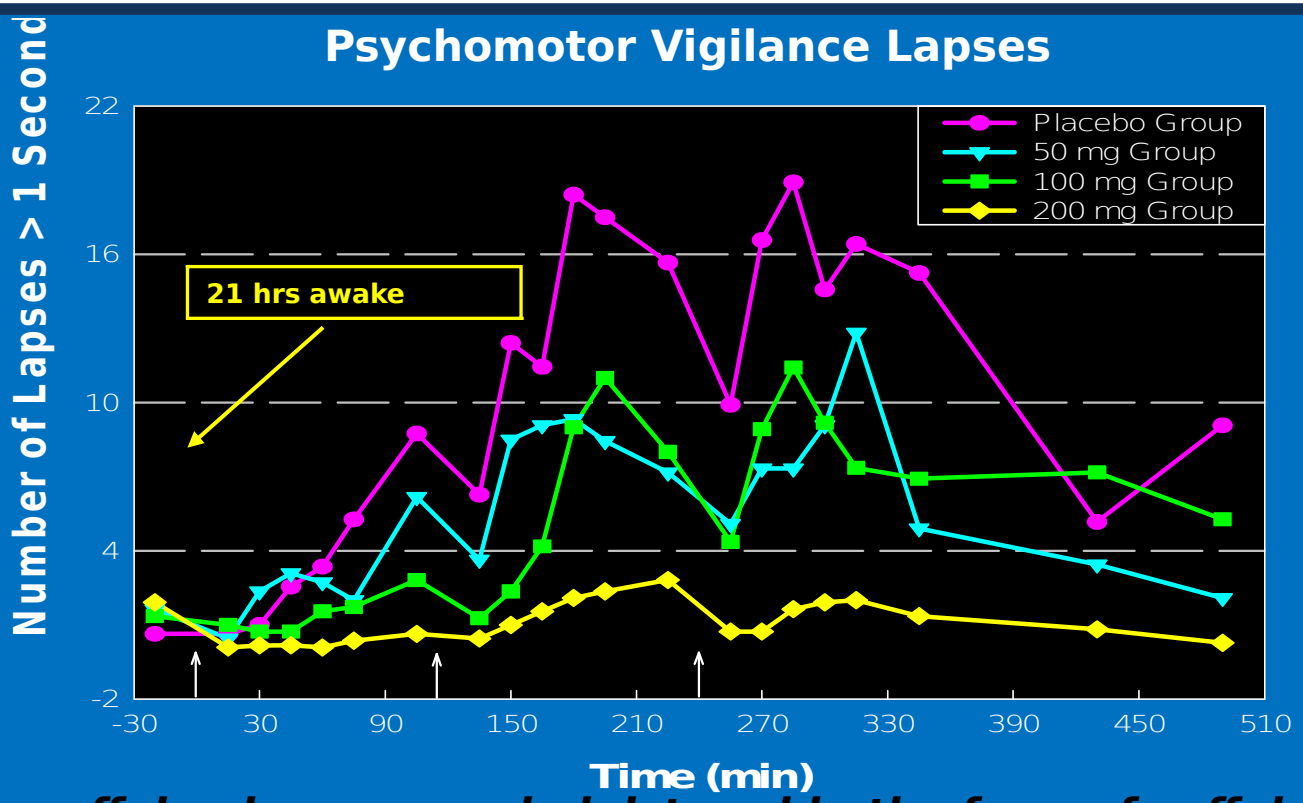

The caffeine here was administered in the form of caffeine gum.

Kamimori GH et al. (2005). Multiple caffeine doses maintain vigilance during early morning operations. Aviat Space Environ Med; 76:1046-1050.

Caffeine and a Nap

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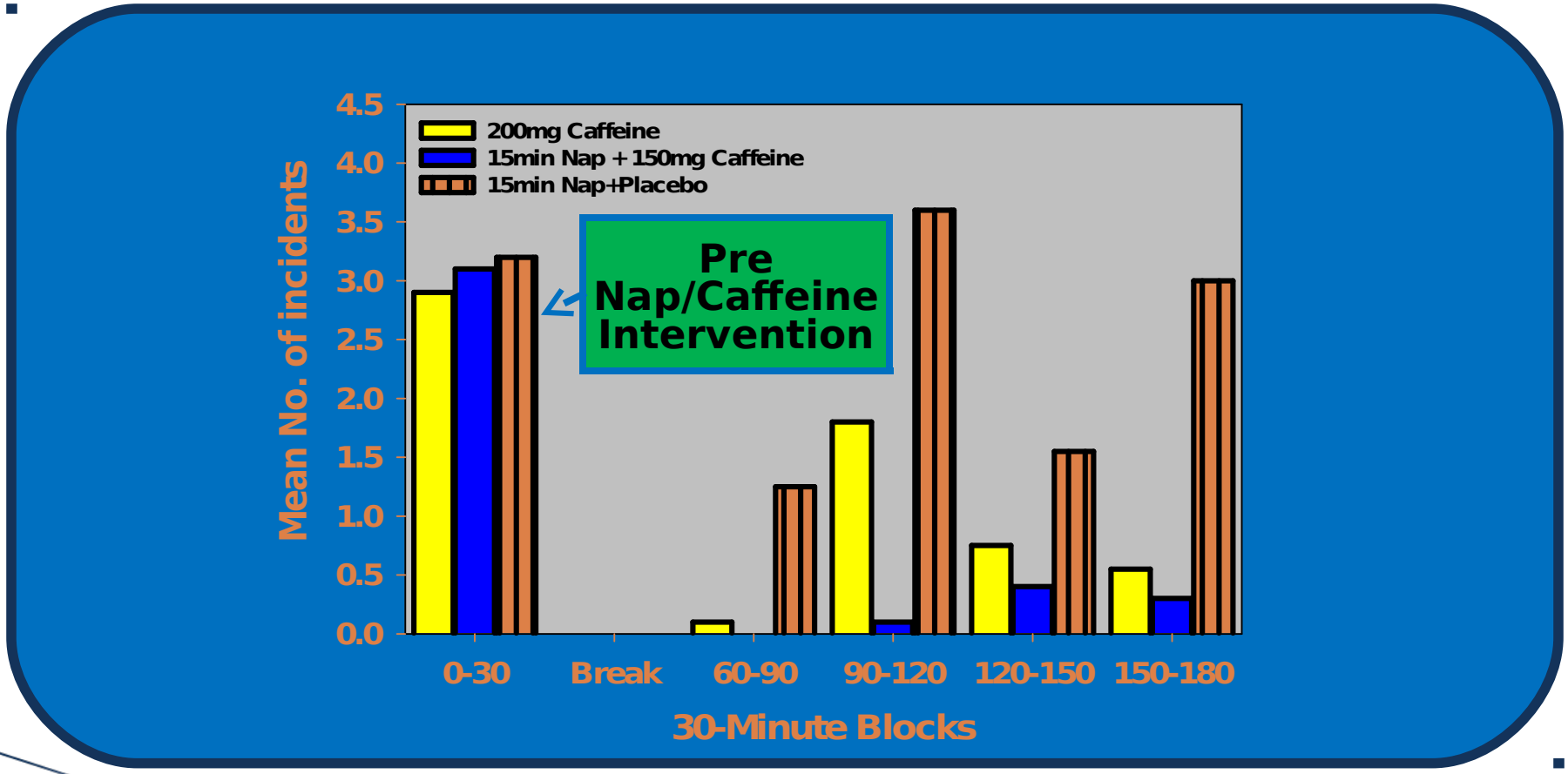

Reyner LA, Horne JA. (1997) Suppression of sleepiness in drivers: combination of caffeine with a short nap. Psychophysiology; 34(6):721-5.

Modafinil

- Modafinil (Provigil®) has been FDA approved for the treatment of narcolepsy and shift-work sleep disorder.
- Studies of modafinil in normals have shown that it significantly improves flight performance, cognitive performance, and alertness.
- Doses ranging from 100-400 mg per day are effective *(currently, 100-200 mg every 8 hours* is recommended).*
- At present, modafinil is not approved for civil aviation.

**BUMED Notice 6410 24 Apr 2012*

Modafinil Sustains Performance

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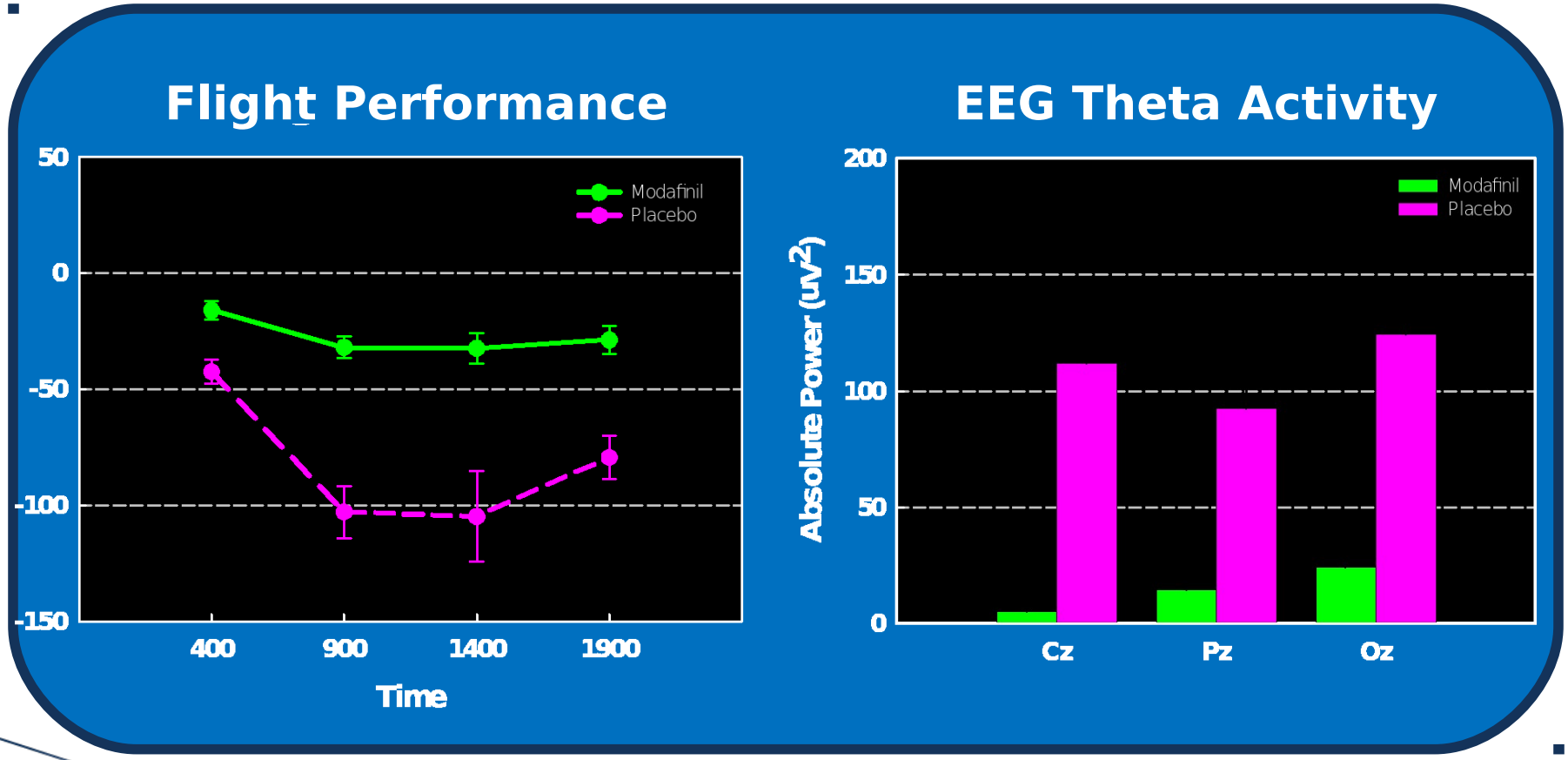

Caldwell JA et al. (2004). Effects 37 h continuous wakefulness on physiological arousal, cognitive performance, mood, & simulator flight performance of F-117A pilots. AFRL-HE-BR-TR-2003-0086).

9) Utilize Rest Breaks

- Help sustain performance and provide physiological recovery, mental stimulation, and improved mood
- Long bouts of work produce fatigue and boredom can seriously impair performance
- Studies have shown that work breaks improve productivity and reduce subjective sleepiness
- Exercise break can be beneficial if *not too strenuous*
- A break at least every hour is recommended
- The more repetitious, boring, and tedious the task, the more frequently breaks should be scheduled

Restorative Effects of Breaks

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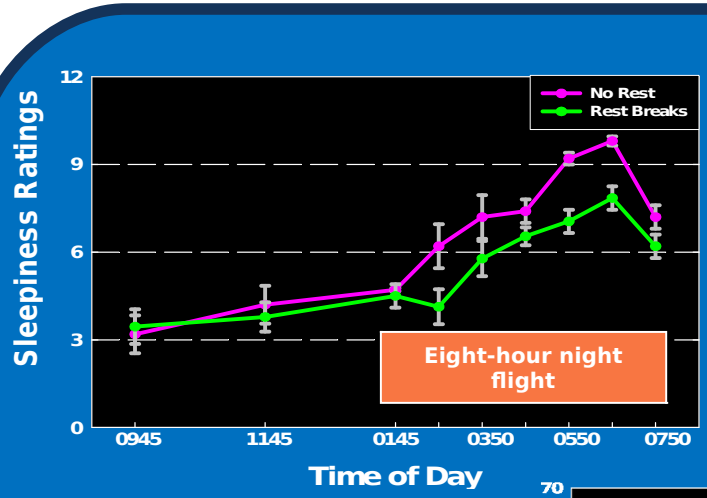
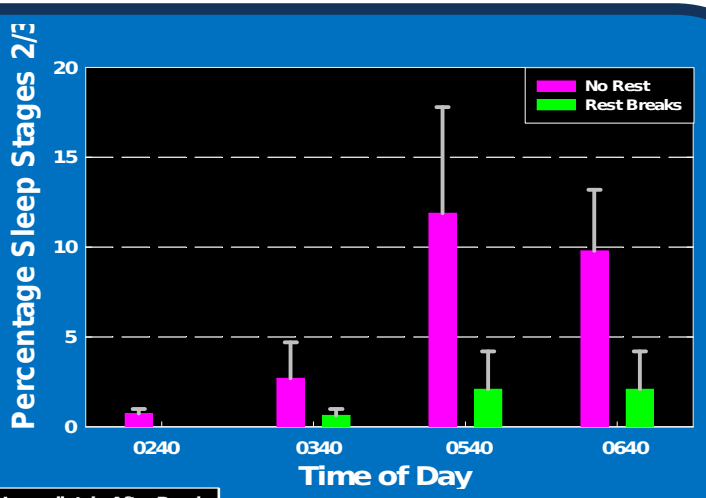
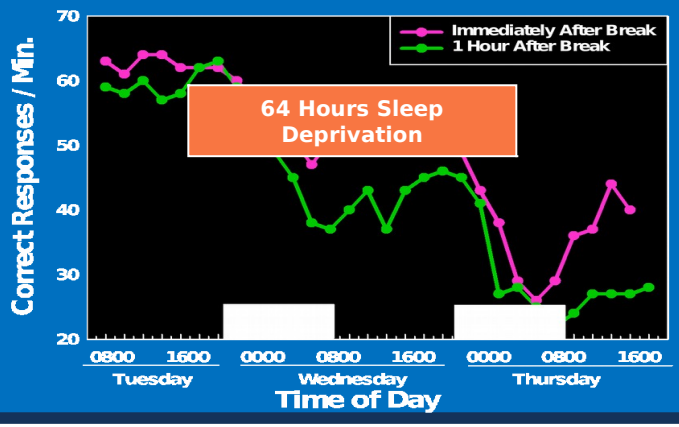






Neri DF et al. (2002). Controlled breaks as a fatigue countermeasure on the flight deck. Aviat Space Environ Med, 73:654-664.

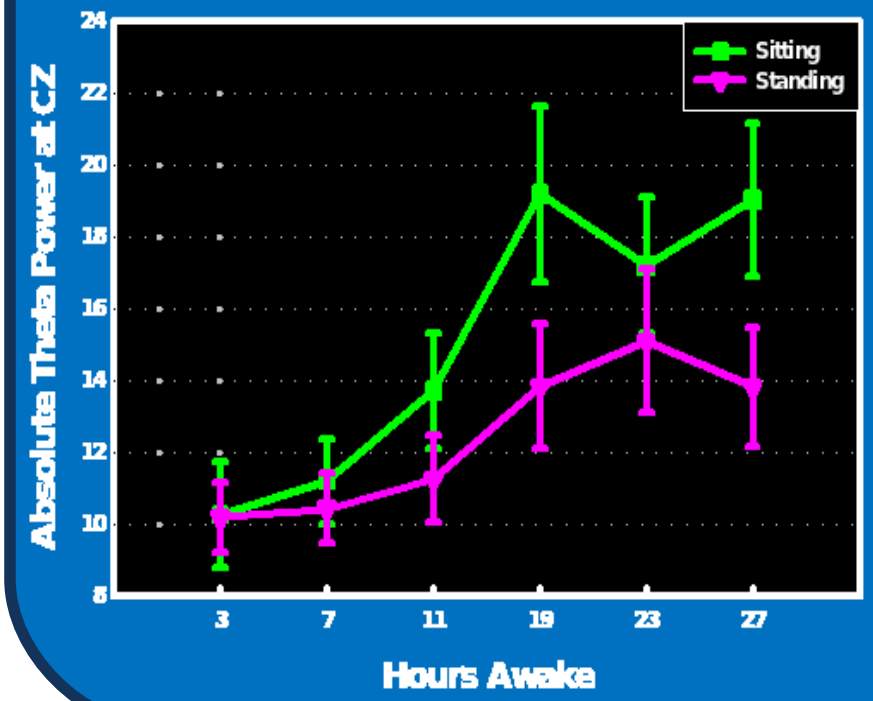
10) Use Body Posture

- The more upright the body's position, the less sleepiness there will be
  - Tilting people upright on a tilt-table causes higher-frequency brain activity than lying flat
  - The less people are allowed to recline in their seats, the less they are able to sleep
  - Narcolepsy patients report less sleepiness while standing than while sitting
- Physiological alertness and performance in sleep-deprived people is better when standing than when sitting
- This is a physiological effect related to baroreceptor firing and noradrenergic activity!

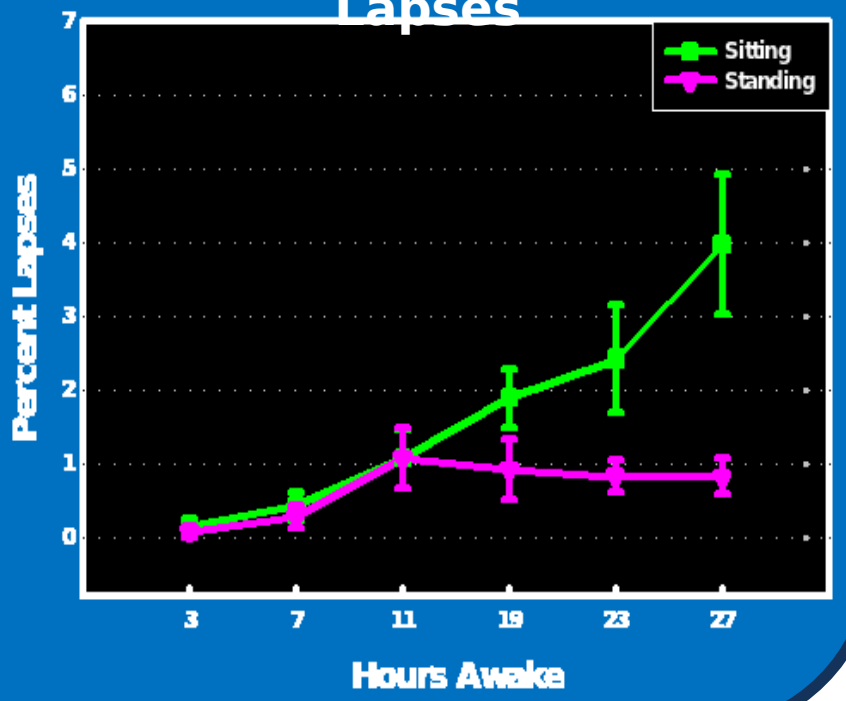
Upright Posture & Alertness

Naval Medical Research Unit Dayton

Slow-wave Brain Activity



Psychomotor Vigilance Lapses



Caldwell JA, Prazinko BF, Caldwell JL. (2003). Body posture affects electroencephalographic activity and psychomotor vigilance task performance in sleep-deprived subjects. Clin Neurophysiol, 114:23-31.

11) Treat Sleep Disorders

- Sleep disorders can significantly degrade sleep quantity and quality
  - Sleep apnea, periodic limb movements, restless legs, etc.
- 24% of males between the ages of 30 and 60 experience sleep apnea
- The American Academy of Otolarynology reveals that a BMI at or above 32 has an 89% positive predictive value for identifying OSA
- Sleep apnea has been identified as a risk factor in motor vehicle accidents

12) Hydration & Nutrition

- It is commonly believed that dehydration contributes to cognitive and physical fatigue
  - One study found that 24 hours without water did not affect cognitive-motor or neurophysiological functioning, BUT did increase subjective tiredness, drowsiness, perceived effort, and concentration
- The role of nutrition is not clear
  - Two studies indicate that high fat content reduces alertness and vigilance, but overall the literature is mixed
  - Lieberman (2003) says large meals tend to be soporific, but the precise macronutrient content of such meals is apparently not critical

Szinnai G et al. (2005). Effect of water deprivation on cognitive-motor performance in healthy men and women. Am J Physiolo Regul Integr Comp Physiol, 289:R275-R280.

Lieberman, H (2003). Nutrition, brain function, and cognitive performance. Appetite, 40:245-254.

13) Supplements?

- **Ginseng**—studies repeatedly show improved alertness and RT after long-term, high-dose use
- **Tryptophan**—weak hypnotic properties
- **Tyrosine**—prevents stress-related declines in mood and cognition
- **Caffeine**—improves vigilance
- **Carbohydrate supplementation**—enhances cognitive performance in individuals exposed to sustained, intense, physical activity
- **Combined taurine, glucuronolactone, and caffeine (Red Bull)**--improves choice reaction time, concentration, memory, and subjective alertness
- **Combined caffeine and glucose**--ameliorates deficits in cognition and subjective fatigue during extended periods of cognitive demand
- **Fat**—may decrease alertness and performance
- **Vitamin/mineral supplementation**—no apparent benefits on cognitive performance or subjective alertness
- **Protein supplementation**—no apparent benefits on cognitive performance or subjective alertness

14) Unproven Techniques

- Many counter-fatigue strategies have not been shown to work well (or at all)
- “Placebo effects” influence subject impressions
- Unless a strategy is validated in the scientific literature, DO NOT use it!
- If in doubt, research it at Entrez PubMed: http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?DB=pubmed
- You can just Google “pubmed” to get there…

You think it might actually work?

If a technique sounds a little crazy… maybe it is. *Check the science before you try it!*

Exercise, Cold Air, and Music?

- **These do not really work!**
- Some research shows that exercise can slightly improve alertness.
  - Effect is short-lived (~20 minutes)
  - Probably leads to more fatigue later
  - Not feasible in many types of operations
- “Cold air to the face” is not scientifically supported
- Listening to music
  - Slightly improves reaction time
  - Slightly decreases subjective sleepiness
  - No evidence that it improves driving or other types of performance

Physical Fitness and Fatigue

- **Physical fitness is not a safeguard!** (although many people think it is)
- Strategy does work well in jobs which require physical labor
- Study: night workers given physical training
  - Fewer subjective complaints
  - Performance was not affected
- Do not depend on physical fitness to overcome fatigue!

Summary and conclusions

- Fatigue is a major contributor to accidents, lost productivity, and poor quality of life
- However, safety, performance, and general operational readiness can be preserved by our proven suite of existing fatigue-management strategies:
  - Adhering to good work-scheduling practices
  - Implementing proven fatigue countermeasures
  - Making adequate daily sleep a top priority
- And ongoing research is advancing the state-of-the-art in fatigue management every day, so *stay tuned for new developments!!*

Questions?

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